BOARD OF TRADE

THE MACHINE TOOL INDUSTRY

A Report by the Sub-Committee of the
Machine Tool Advisory Council
appointed to consider Professor Melman's Report
to the European Productivity Agency

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PART I

Introduction

1. At its meeting on 2nd December, 1959, at which the President of the Board of Trade and the Paymaster General were present, the Machine Tool Advisory Council considered a report* by Professor Seymour Melman on the machine tool industry of Western Europe and decided to set up a sub-committee, with Sir Steuart Mitchell of the Ministry of Aviation, a member of the Machine Tool Advisory Council, as Chairman, and with the following terms of reference :

> To consider the report by Professor Melman prepared for the European Productivity Agency Project No. 420 and to report to the Machine Tool Advisory Council what action could usefully be taken by the United Kingdom machine tool industry on his recommendations.

2. The original members, representing the machine tool industry, user industries, the Trades Union Congress, and the Board of Trade were :

Mr. R. W. Asquith : Asquith Machine Tool Corporation.
Mr. W. J. Carron : Amalgamated Engineering Union.
Colonel C. W. Clark, D.S.O., O.B.E., M.C. : Alfred Herbert Ltd.
Mr. R. C. Giggins : General Electric Co. Ltd.
Mr. E. T. Grainger, O.B.E. : Board of Trade.
Mr. J. G. Lloyd : Vickers Armstrongs (Engineers) Ltd.
Mr. J. B. L. Munro, C.B., C.M.G. : Board of Trade.
Mr. R. D. G. Ryder : Thos. Ryder & Son Ltd.
Mr. A. Siddall : Jos. Lucas (Electrical) Co. Ltd.

with

Mr. K. D. Rogers : Board of Trade, as Secretary.

Dr. E. Lee of the Department of Scientific and Industrial Research was co-opted as a member early in the Sub-Committee's proceedings. Mr. Doughty of the Association of Engineering and Shipbuilding Draughtsmen has on occasion attended as alternate to Mr. Carron, and Mr. B. C. Harrison, a Director of Alfred Herbert Ltd., has attended several meetings on behalf of Colonel Clark.

3. Professor Melman's report, which has not been published, was circulated by the Director of the European Productivity Agency to a restricted circle of interested parties in the belief that it merited open and critical discussion. This was consistent with the general policy of the Agency of promoting the examination of economic and technical factors influencing productivity and did not imply that the Agency endorsed the views expressed by Professor Melman. These views have been made known to a wide audience by Professor Melman himself in the course of recent visits to Europe and, while his report cannot for the time being be published, the main issues have been widely discussed and are properly matters of public interest.

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* Report on the Productivity of Operations in the Machine Tool Industry in Western Europe, prepared by Professor Seymour Melman, Associate Professor of Industrial Engineering at Columbia University, New York, for the European Productivity Agency.

4. We held our first meeting on 28th January and have held 20 meetings in all. We wish to express our appreciation of the help given by those who were good enough to meet or to write to the Sub-Committee and to give their views on Professor Melman's criticisms of the West European machine tool industry and associated matters. In particular we would express our thanks to Professor Melman, who expounded his views to us at our second meeting and had further informal discussions with the Chairman towards the end of our enquiry.

5. Professor Melman's main recommendation is that mass production methods of manufacture must be introduced rapidly into the machine tool industries of Western Europe, firstly to provide efficient machinery at low prices to user industries, and secondly to enable the West European machine tool industries to stand up successfully to competition from " other mass producers of machine tools ".

6. To implement this main recommendation, Professor Melman proposed a series of specific investigations into design problems, performance, production methods and markets.

7. We consider first in this Report Professor Melman's main recommendation that the machine tool industries of Western Europe should adopt mass production methods. We then go on to consider his detailed proposals for the specific investigations referred to above. Finally we offer our comments on certain other aspects of the United Kingdom machine tool industry, its structure, and its strengths and weaknesses as we see them.

PART II

Professor Melman's Main Proposition: Mass Production of Machine Tools

8. Professor Melman's main recommendation is that mass production methods of manufacture must be introduced rapidly into the machine tool industry of Western Europe. He considers that such a course is urgently required in order (i) to provide efficient machinery at low prices to user industries; and (ii) to enable the West European industry to stand up successfully to competition from other mass producers of machine tools.

9. It is important to be clear as to what is meant by the term " mass production ". In our view true mass production refers to production lines specially set up for continuous production of one specific product for long periods. This is what Professor Melman saw in the Krasnii Proletarii plant in Moscow and which, we understand, forms the basis for his recommendation. These techniques differ in degree from batch production, even when the latter is conveyorised or where multi-station machines are used on some components, since the long runs of work in true mass production justify a more comprehensive investment in plant, jigs, tools, &c., all specialised to the specific product. It is this fully equipped mass production that is recommended by Professor Melman.

10. We have given careful consideration to this recommendation but do not find ourselves able to agree with it for the reasons set out below.

11. To set Professor Melman's main recommendation in proper perspective we think it necessary to point out that true mass production methods are applied in the U.S.S.R. to only a small sector of machine tools. Our information is that in the whole of the Soviet machine tool industry true mass production is used only in the case of one size of centre lathe, with plans for possible extension to two other designs of machine tool. The major portion of the output is in fact manufactured by the methods used in the West, *i.e.*, batch production, in some cases with conveyorised assembly, and manufacture of individual special machine tools.

12. Professor Melman himself recognises that these mass production methods are only economical if there is a high and stable demand for the product. Further, we know from our discussions with him that he has come to the view that outside the Communist *bloc* the limits of any single country are too narrow to provide a demand for machine tools sufficiently high and stable for the application of mass production techniques. He agrees that some form of international centralisation of demand, standardisation, and production would be required, but he does not suggest how such arrangements could be brought about.

13. The national and international problems that would arise in any such centralisation are not only formidable but go much wider than the machine tool field. We see no likelihood of such a far-reaching degree of international planning being achieved in the foreseeable future, nor do we consider that any initiative in that direction by the machine tool industry alone would be likely to succeed. To this we would add that for a variety of reasons we do not regard the extreme regimentation and control necessary to create these conditions as being acceptable to democratic and sovereign countries. The essential basis for mass production on this scale is therefore unlikely to be achieved within any reasonable period ahead.

14. We are, moreover, satisfied that, so far as European manufacturers are concerned, even if by some system of rationalisation by international decree the number of types and sizes of machine tool outside the Communist *bloc* were reduced to an absolute minimum, and even if the difficulties of concentrating the resultant production of each type into one firm were to be overcome, the demand would still be too low to justify real mass production methods. For example, even in the case of the most common type of centre lathe, the maximum annual demand for any one model would not exceed a few thousands yearly because of the unavoidable variants of size, type, quality and performance. Such quantities are too small for the economic application of true mass production techniques. We agree that economies in costs would result from the larger batch series that would ensue from such centralisation, but the end result would be batch production and not mass production.

15. The circumstances which have led the U.S.S.R. to apply mass production techniques to a few simple types of machine tool arise from the huge captive market, the severe limitations by decree of types and sizes of machine, and the exceptionally large and long programme for initial equipping of new industrial areas in the Communist *bloc*. These circumstances are favourable to the mass production of simple standardised machine tools, but this combination of circumstances does not obtain elsewhere.

16. Throughout his Report Professor Melman in our view overstresses the importance of the price of machine tools. Between machine tools of equal performance the user naturally attaches importance to price, but the decisive consideration in assessing the worth of machine tools of differing performance is the ability of the particular machine tool to reduce the cost of the product it makes. In manufacturing costs the price of the machine tool is only one element and is generally small in comparison with the other elements of overall cost. A study we have made of this indicates that in typical large jobbing engineering factories even as large a reduction as 25 per cent. in machine tool prices would represent of itself only between 1 per cent. and 2 per cent. of overall manufacturing costs. To an ever growing extent overall production costs are *reduced* by the use of high performance machine tools in spite of their higher price.

17. United Kingdom machine tool manufacturers could quickly introduce mass production methods once they were convinced of the existence of a demand for the increased output which would result, and the disposal of which is not considered in Professor Melman's Report. For the reasons given above we do not consider that any reduction in price resulting from mass production would generate the necessary increase in demand.

18. It has to be recognised, nevertheless, that in the narrow field in which the Soviet machine tool industry is " mass producing ", it may well be able to produce cheaper machine tools than those produced in batches, and that, assuming comparable performance, these tools will have a sales advantage, if after satisfying their domestic needs there is surplus production for sale abroad. This may mean that the countries of the West will have to meet a serious challenge in markets which are important to them ; and it has to be recognised that this challenge will be the more serious because the economic system in the Communist countries enables them to sell abroad at prices which do not reflect true costs of production. Moreover they may be ready to support their sales effort with loans and credits at lower rates of interest repayable over a longer period than exporters in Western countries are able to offer. This ability of Communist countries to undersell Western countries for politico-economic reasons has to be borne in mind when considering whether it is worth while to take special steps to counter the threat of competition from these countries in the market for a particular product. Appendix A summarises the views of the machine tool manufacturing members of the Sub-Committee on the Soviet threat to United Kingdom exports of machine tools. They conclude that this threat is a real one in regard to simpler standard machine tools and can be expected to intensify, particularly in the less-industrialised countries. In the case of the more advanced types of standard and special machine tools, the manufacturers consider that the United Kingdom industry should be able to compete, provided its development effort is adequate.

19. We consider that our best course in those markets in which Soviet competition exists or is likely to appear is to ensure the technical superiority of our designs over those of rival machines offered at lower prices—whether these prices are based on genuinely lower costs or not. This will be no easy matter for the U.S.S.R. are themselves concentrating great efforts on machine tool research and development (*see* paragraph 23). We go on to consider later in this Report the steps that the United Kingdom machine tool industry needs to take to enable it to produce machine tools of more advanced design.

20. Mass production of machine tools essentially implies standard and general purpose designs. The clear trend in the more highly industrialised countries, however, is for the concentration of production in the machine tool *using* industries into larger production units. This trend, coupled with rising labour costs, results in a growing demand for complex, high performance, specialised machine tools, the output of any one type of which is small and unit cost high. They are the antithesis of the mass produced machine tool.

21. It is our view that those countries which are as yet less highly industrialised will in the long term follow this trend. This is another reason for thinking that the market outside the Communist *bloc* for simple standard machine tools, while it will continue to be large and important, will not increase to an extent which could absorb West European output on a truly mass production basis. Furthermore there is a growing tendency, already present in India and Latin America, for the less industrialised countries to set up their own machine tool industries, starting naturally with manufacture of simple standard machines. This will reduce the potential export market from Western Europe and the Communist *bloc* for these types.

22. In this connexion, it may be significant that the curve of Soviet machine tool production is flattening out after the rapid increases of the mid-1950s, as shown in the following figures :

Period	*Yearly increase in Total Soviet Machine Tool Production*
Five-year Plan 1951-55 ..	Average achieved 10·7 per cent. per annum
Five-year Plan 1956-60 ..	Planned 13·8 per cent. per annum Actually achieved 5·6 per cent. per annum
New Seven-year Plan 1959-65	Planned 5·5 per cent. per annum

By comparison, United Kingdom production increased by about 7 per cent. per annum during the period 1951-59.

23. It would be unfortunate if the emphasis which Professor Melman has given to his recommendation for " mass producing " machine tools had the effect of diverting attention from the importance Western industry should attach to the Communist *bloc's* concentrated effort on research and development. So far Soviet production has been to a considerable extent dependent on the rapid flow of developments hitherto produced by Western manufacturers. We are, however, impressed with the evidence of the great efforts which are being made in the U.S.S.R. to develop machine tools of more advanced design.

24. Although we have not been able to accept Professor Melman's main recommendation we are in agreement with him that important advantages are obtained when manufacture is carried out in large production units and consider that there remains scope for further rationalisation in some sectors of the United Kingdom industry.

25. Even more important than the economies which can be obtained from larger batch production is the fact that larger industrial units are better able to carry the greatly increased research and development effort which we consider to be vital to the well-being of the United Kingdom machine tool industry (*see* paragraphs 95 to 102).

26. Our conclusion, therefore, on Professor Melman's main recommendation is that we disagree with the proposal that " mass production " of machine tools should be introduced in the West, partly because we consider that the essential conditions of high, stable, and controlled demand are unlikely to be created within any foreseeable period of time and that, even if they were, demand would not be sufficient to justify mass production (though cost economies would follow from increased rationalisation and increases in the size of batches produced) ; and partly because the extreme standardisation of design implicit in mass production would not meet the growing needs of user industries for high performance machine tools both standard and special.

PART III

Professor Melman's Detailed Recommendations

27. In the light of our consideration of Professor Melman's main recommendations on mass production, outlined in Part II above, we have examined his specific proposals.

Standardisation and Centralised Production of Components

28. Professor Melman proposes an investigation to establish what proportion of machine tool requirements could be met out of a standard series of components, and to what extent the manufacture of standardised components could be centralised into specialist factories.

29. As regards standardising components there are already both national and international standards in machine tool components, *e.g.*, bearings, spindle noses, splines, serrations, keys and drill sockets, but the extent is small compared with what Professor Melman has in mind. It must be recognised, however, that the detailed design of an individual component has to be integrated into, and therefore to an appreciable extent made subordinate to, the overall design and concept of the machine tool. This limits the extent to which standardising component design is feasible.

30. The manufacture of standardised components is already centralised in the United Kingdom to a considerable extent. There is a natural cost inducement to use standardised parts particularly those which are produced in quantity for the engineering industry generally. Machine tool makers also to a considerable extent buy from specialised producers parts more specifically required by the machine tool industry, *e.g.*, electrical equipment, ball and roller bearings, hand-wheels, handles, pumps, clutches, couplings, tool holders, boring bars, arbors, dividing heads, circular tables, chucks, and other tooling equipment. As for gears, most machine tools require for their successful operation certain performance features which are not so necessary in the case of more common gears and to that extent some specialisation in the case of machine tool gears is often unavoidable. Although many machine tool makers buy gears from specialised producers most find it necessary to supplement this source by making their own special requirements ; but even here there is a considerable measure of centralised production since the larger machine tool manufacturers sell gears to small firms in the industry.

31. We see little likelihood of any major advance in the extent either of standardisation or of centralised production of components except as a result of rationalisation of designs of similar types of machine tool. Accordingly we do not consider that the special investigations proposed by Professor Melman are necessary. We would expect, however, that surveys similar to that which he proposes would naturally be put in hand by firms making similar types of machine tool who decide to rationalise their designs.

Need for Standardisation in the Tooling Area

32. We consider, however, that one aspect of standardisation, not referred to by Professor Melman, should receive more attention. This is the standardisation of those parts of machine tools which are of primary importance to users, particularly those features which are associated with the attachment and location of work pieces, tooling and ancillary equipment. We have in mind particularly uniformity of table sizes and pitch of tee slots on milling machines, and more standardisation of spindle centre heights on certain types of boring machines and of tooling and equipment for standard machine tools, *e.g.*, tool holder attachments and jig and fixture attachments of all kinds.

33. We recommend that the machine tool industry should set up an effective organisation to establish greater standardisation in those areas of primary interest to users. This organisation should act in close consultation with users and, where appropriate, with the British Standards Institution.

Modular Units and Standardisation of Unit Heads

34. Professor Melman proposes an investigation into the possibilities of constructing both general and special purpose machines from modular units. We agree with Professor Melman that the widest practicable use should be made of modular units in the construction of machine tools. Modular units can be divided into two broad classes :

(*a*) those which can be satisfactorily used only in the construction of a particular basic type of machine tool, and

(*b*) those which are interchangeable and which can be used in more than one basic type of machine tool.

35. As to (*a*) these include unit heads, columns, bases, tables and platens for straight-line machines, indexing table and drum type machines and single station, one, two or multi-way units for drilling, milling, boring, reaming, fine boring and other operations, and also such items as spindle assemblies, feed boxes and knees for milling machines. The use of such units is already fairly common practice in the United Kingdom machine tool industry. Machine tools incorporating these units are widely used by many firms in the engineering industry, such as those manufacturing motor cars, motor-cycles and cycles, domestic appliances and machinery, ammunition filling and inspection equipment, printing and processing machinery, rotating electrical machinery, switchgear, portable power tools, boot and shoe machinery, tobacco and cigarette machinery, and ball and roller bearings. The modular units mentioned by Professor Melman in connexion with the Ford Motor Company, Detroit, fall into this category. While we are in agreement with Professor Melman as to the advantages of modular construction in this field, we consider that these advantages are already widely known and are being well exploited, and that a special investigation is unnecessary.

36. We invite attention to the desirability of greater standardisation of those details used for assembly and location of unit heads. In particular we have in mind greater standardisation of the mounting and attachment surfaces and the bolting patterns, for main and wing bases, vertical and angular columns, horizontal angle adaptors, and feed units. Greater interchangeability in these respects would substantially benefit user firms seeking greater flexibility in transfer lines or in multi-station machines. Accordingly we recommend that leading manufacturers of machine tools incorporating unit heads should collaborate to achieve greater standardisation of these details. We believe that the standards now accepted by the American automobile industry, based on the Ford Motor Company's work, could well be adopted as international standards and that to promote this objective the United Kingdom machine tool industry should adopt them as soon as possible.

37. As to (*b*), the suggestion implies the use of one unit for a number of different basic operations performed on standard general purpose machines, *e.g.*, the use of one spindle head for a centre lathe, a milling machine and a boring machine. In general we consider that to construct standard machine tools from units common to more than one type would prejudice the design of a functionally satisfactory machine. The evidence we have received is that such machine tools are makeshift affairs only useful when put together by users to meet an exceptional need. Our conclusion is that the scope for such application is small : that except in special cases the savings in cost would be small in relation to total machine tool costs : and that this small saving would be more than offset by penalties to the overall design of the machine tool. We do not consider that further investigation would be justified.

The Extent to which Special Machine Tools are Necessary

38. Professor Melman proposes an enquiry to establish whether special machine tools are really necessary to the extent at present demanded, and to examine the possibilities of constructing such as are necessary from standardised components.

39. The implication of these questions falls into two parts. Firstly, that the use of special machine tools should be reduced thereby increasing the demand for standard machine tools and reducing their cost. Secondly, that by a widespread use of modular design the user could obtain his specialised needs by selecting appropriate modular blocks ; and as these, by Professor Melman's hypotheses, would be standardised, the machine tool user would obtain his specialised assembly more cheaply than by buying a specialised machine tool.

40. The first part of Professor Melman's proposition over-simplifies the position. What is true of highly industrialised countries is not true of those which are less industrialised. The latter still predominantly need standard general purpose machine tools. The former are increasingly demanding special machine tools, as manufacturing industry there is progressively centralised into fewer larger and more specialised units (*see* paragraph 20). If these special machine tools cost more than standard machine tools would have cost, the higher price is paid only if the user is satisfied that it will be more than offset by lower production costs.

41. We have said in paragraph 16 that the user attaches importance to price as between machine tools of equal performance ; but the determining factor is the cost of the end product and it is more and more true to say that more costly equipment must frequently be bought if production costs are to be lowered. The machine tool is the servant of the engineering industry, and user industries would be foolish to seek lower equipment costs at the expense of higher manufacturing costs. It is the judgment of the user industries in their search for lower costs or higher quality of the end product which, applied case by case over the whole field of the engineering industry, determines demand for the relevant proportions of special and standard machine tools ; and we consider that the investigation into these proportions proposed by Professor Melman would be neither practicable nor useful.

42. The second part of Professor Melman's proposition recommends greater use of standardised parts and modular units in special machine tools. This covers much the same ground as that already covered in paragraphs 28 to 37 above. It will be convenient if we summarise our views as follows :

(*a*) We agree that further standardisation of components would be advantageous. We consider, however, that this can only come about if the number of machine tool designs is reduced and that there is little likelihood of this except by rationalisation of production in firms making similar types of machine tool.

(*b*) We agree with Professor Melman that modular construction is very advantageous for specialised multi-station machines, but we consider that this is well recognised and is already being actively exploited (*see* paragraph 36).

(*c*) We consider that there is little scope for the greater use of modular construction in highly specialised machine tools.

(*d*) We agree with Professor Melman that greater use should be made of modular construction in standard machine tools, but only if performance does not suffer. The practice is in fact growing amongst larger firms in the United Kingdom machine tool industry ; and, though we would like to see the development accelerated, we do not think that an investigation on the lines which Professor Melman proposes would be appropriate, since the basic principle is well recognised.

Process for Formulating Standards

43. Professor Melman calls for an enquiry into how the processes of establishing standards could be simplified and speeded up.

44. We are in agreement with this. The present processes are prolonged and in many cases it takes several years to complete the establishment of a new standard. If, as we understand to be the case, lack of technical staff is one of the chief reasons why progress is so slow, then we would suggest that the benefits to industry generally of greater standardisation are sufficient to justify the cost of a staff adequate for the purpose. We recommend that the relevant bodies—the Machine Tool Trades Association, the British Standards Institution and the Federation of British Industries—should be invited to look into this matter.

Major Problem Areas for Development of Machine Tool Design

45. Professor Melman suggests that an assessment be made of the resources needed for research into the development of machine tool design and of the main sectors to which it should be directed. We regard the question of research and development effort as of paramount importance and we offer views on it in paragraphs 95 to 102 below.

The Extent to which certain Principal Features built into Machine Tools are Actually Utilised

46. Professor Melman suggests that there is a persistent demand from machine tool users for increased power and versatility in the machine tools they buy ; that this demand can often only be met at a substantial increase in machine tool costs ; and that since many of the features built into machine tools—he mentions horsepower, size of workpiece, range of speeds and feeds and precision—are, in fact, not utilised, it should be possible to reduce the range of performance and number of features offered and so effect direct savings in cost. He suggests an investigation into this question based on two important classes of machine tool selected for the development they have undergone in respect of performance characteristics.

47. Users at home and abroad naturally buy according to their own production needs and not those of machine tool makers, and our evidence supports the view that they neither wish to buy nor are forced to buy greater performance or wider versatility than they consider to be economic for their own purposes. It is significant that when they buy tools from abroad, as they do on a considerable scale, United Kingdom users do so primarily to obtain additional features or performance.

48. As a general rule it is true to say that the benefits conferred by simplification of design are bought at a sacrifice in range and quality of performance. If United Kingdom manufacturers were to limit the performance of their machine tools it would almost certainly result in users going abroad for machine tools incorporating the special features they require. This is illustrated by the fact that machine tools produced during the last war to over-simplified patterns proved difficult to sell afterwards because of their restricted applications.

49. Finally, a sizeable proportion of the demand for standard machine tools comes from firms engaged in batch production of a variety of differing products with a consequential need for versatility and a wide range of performance in their machine tools. In such conditions the user naturally looks for a wide range of features, *e.g.*, power, work size, speeds, precision, when selecting a standard machine, knowing that for any particular job he is unlikely to require them all, but equally knowing that over a period he will do so. For the reasons outlined above we do not consider that any useful purpose would be served by an investigation on the lines proposed by Professor Melman.

The Extent to which High Precision Machine Tools are an Efficient Alternative to Multiple Machine Processing

50. Professor Melman argues that machine tool manufacturers are under constant pressure to incorporate higher degrees of precision in their products, so that a single high-priced machine can turn out finished work and avoid the

need for a second machine to undertake final processing. He advocates a special investigation to examine the merits of providing separate machine tools for the earlier processes which, because of the lower degree of accuracy required, could be of cheaper quality.

51. To reduce the precision of the machine tool so that only partially finished work can be turned out on it, leaving the finishing process to be performed on other machine tools, would in most cases add to the overall costs incurred by the machine tool user. Labour and material handling costs would be substantially increased ; economic machine loading would be more difficult to programme ; and additional and often substantial costs would arise from the need for extra jigs, tools and fixtures. The majority of machine tools, as they reach the second half of their lives, progressively lose their initial precision, and a natural use for these older machine tools is on the less precise machining jobs.

Assessment of the Quality of Machine Tools Manufactured in Eastern Europe and China

52. Professor Melman proposes a technological assessment of the quality of machine tools manufactured in Eastern Europe and China. Whilst we are satisfied that Soviet machine tools are of good quality we consider that an assessment would be useful ; we have arranged for one to be carried out and a report will be submitted to the Council in due course.

Alternative Production Processes, Layouts and Factory Organisation

53. Professor Melman recommends two subjects for special enquiry in connexion with production methods. They are :

(*a*) alternative methods of manufacturing machine tools, for small, large and continuous quantities ;

(*b*) alternative methods for production organisation in order to improve technological efficiency in small-batch, large-batch, and continuous production conditions.

54. As to (*a*) above, the decision in a firm regarding the production methods to be used, and the scale of investment in tooling, equipment, mechanical handling, &c., depends on the quantities to be made which in turn depend on forecasts of sales. We see no reason to suppose that in general the managements in machine tool firms are not aware of the importance of careful estimating in these matters or that they are not well informed by cost analyses and sales research as to the facts on which their judgments must be based. Consideration of these matters is a part of normal day-to-day management and we see no justification for a special enquiry on the lines which Professor Melman proposes.

55. As to (*b*) above, the possibilities of changes vary widely from firm to firm and depend not only on shop techniques but also on capital resources, market forecasts and the individual nature of the product. It would in our view be impracticable to make an investigation of the type proposed which could have any general application to the machine tool industry as a whole. Moreover, in the case of the smaller firms, which are the most numerous, the scope for such changes is strictly limited. We consider that managements in the machine tool industry realise the importance of these matters and we have

noted that a number of firms in the industry employ outside consultants to advise them. We do not, therefore, consider that a special enquiry into production organisation in the industry would be worth while even if it were practicable.

56. Professor Melman himself told us that he had no criticism to make of machine tool production methods in the United Kingdom in relation to the quantities produced. There is, however, no room for the machine tool industry to be complacent about its production techniques. There is certainly as much scope for the critical examination of existing methods and for the employment of new techniques in the machine tool industry as in other industries. It has, as supplier of production equipment to the engineering industry, constant access to the most up-to-date production techniques of its customers. Though we are satisfied that the leading firms apply these techniques to their own production wherever it is advantageous to do so, there are in this industry, as in most others, wide variations in the ability of managements to adopt fresh manufacturing methods and in their readiness to invest in new equipment. In particular we wish to stress the fact that the shortage of qualified engineers in the machine tool industry as a whole (*see* paragraphs 91 to 94) makes it difficult for many firms to keep abreast of the latest production techniques.

Application of Electronic Controls to Machine Tools

57. Professor Melman states that only a few machine tool firms in Western Europe have been exploring the techniques of machine tool design that are necessary to adapt machine tools to numerical control of operations. He considers that electronic control of machine tools is likely to be of growing importance to the productivity of operations within the machine tool industry and among users of machine tools. He recommends an investigation to determine what technological and economic possibilities exist for the modular design and production of numerical control systems : and also into the most economical ways of constructing numerical control equipment since major price reductions would in his view encourage greater use of such units.

58. Electronic control of machine tools at present falls into two main categories : for co-ordinate positioning and for contour milling. We consider that the situation as regards co-ordinate positioning is reasonably satisfactory in that a considerable effort is already being put into its development by a number of United Kingdom firms in competition with one another. Its advantages are clear and easily demonstrable and its use by United Kingdom industry is growing fast.

59. Our conclusions concerning more complex forms of electronic control particularly for contour milling are as follows :

(*a*) We agree with Professor Melman that few machine tool firms are adequately equipped to explore the techniques of machine tool design that are necessary for use with electronic control. We invite the attention of makers of those types of machine tool suitable for electronic control to the long-term importance of this and recommend a substantial increase in development effort in this field.

(*b*) Modular construction is a well established and widely used custom in electronics and is already utilised in machine tool controls. It is true that the costs of components and sub-units form a large element in the total costs of machine tool control equipment, but these components in the majority of cases are already being used in much greater numbers for other electronic equipment and the total numbers ever likely to be used in machine tools are small in relation to the general electronic market for these components. Hence even an extreme degree of standardisation and modular construction within the machine tool control field would do little to cheapen the price of such components.

(*c*) It is our view that the electronic firms concerned in machine tool control are already widely experienced in a highly competitive industry with a good export record, and that no purpose would be served by the investigation into the possiblities of more economical construction proposed by Professor Melman. The need for reduction in the price of electronic controls is already fully appreciated by the firms concerned.

(*d*) We note the hesitation which the United Kingdom engineering industry is so far showing in the use of the more complex forms of electronic control of machine tools for contour milling. There is good reason to believe that electronic controls manufactured in the United Kingdom are still ahead of any foreign competitors and there is a good *prima facie* case supported by actual tests to show that within a wide field of batch production substantial savings in costs can be obtained with these controls even at their present high prices. Yet, although there are signs of quickening interest, British industry is still not using them to any appreciable extent. Two reasons for this are the high price of electronic controls and lack of belief in their reliability. A more important reason, however, is the almost complete lack of information on the real economics of electronic controls, and we consider that the key to the problem lies in providing much better factual cost information to the engineering industry on the use of these new techniques than has so far been available to them. Such information, to be accepted, must be based on full cost analyses of production by user firms. A useful start has been made by the Royal Ordnance Factories who have recently carried out small trials under controlled conditions. We understand that their report is shortly to be published. We believe that further trials, of wider scope and under the direction of an independent authority, should be carried out and we recommend that the Government should consider whether their resources could usefully be made available to assist these experiments.

(*e*) We wish to emphasise the need for a clearer understanding and greater awareness on the part of machine tool firms of the growing importance to them of electronic and control system engineering techniques, not only for control of machines but also for built-in inspection facilities and for integration into systems employing electronic design data processing. We consider that the necessary dovetailing of machine tools and electronics is best handled case by case by an association between the machine tool manufacturer and an experienced electronics firm already engaged in a wide electronic field. We do not recommend that machine tool firms should become manufacturers of electronic control equipment, but are strongly of the view that each firm manufacturing machine tools of a type to which electronic controls or inspection could advantageously be applied should have on its staff sufficient engineers with the necessary qualifications to understand fully what electronics can and cannot do, to form a link in a joint activity with an electronics firm and to handle the subsequent technical sales problems.

(*f*) The need for greater understanding and use of electronics in the machine tool industry will be greatly helped by the plans currently being evolved by the Department of Scientific and Industrial Research and the Machine Tool Trades Association in regard to the research and development requirements of the industry. We wholeheartedly support these plans and we invite the attention of the machine tool industry to the importance of making full use of the educational facilities now being offered for both senior and junior staff.

(*g*) We draw attention to the need for a more basic approach to the problem of applying electronic techniques to machine tools. If the potential of electronics is to be fully utilised fundamental work has to be done in machine tool design, for example, in the field of friction and stiction of slides, drive transmission, elimination of backlash and elastic strain, rigidity and dimensional stability, elimination of vibrations and reduction of mass inertias and indeed in entirely new concepts of tool motion. It is also important that the potential of built-in electronic inspection should be investigated as an integral part of machine tool design inspection. These problems should be investigated by joint teams of machine tool and electronic control system engineers, and we recommend that the necessary research should be carried out in industry partly through development contracts placed by the appropriate Government Department.

Quality Control of Precision Components

60. Professor Melman suggests that information should be sought as to how the qualities of high precision can best be controlled when an item is produced in varying quantities. We assume that Professor Melman is referring to control by factory inspection and we see no point in undertaking research such as he recommends. This is not a new problem and there is in existence a large body of expert technical knowledge and an extensive literature.

61. We think that what Professor Melman has in mind in his proposal is the avoidance of the high inspection costs involved in the 100 per cent. inspection normally called for on small batch production jobs. This, in our view, depends on the extent of jigging and tooling used in production which in turn depends on the quantities to be produced. We would agree with Professor Melman that the increased size of batches, which is the main purpose of his recommendation,

should permit of more extensive tooling and thus of the use of quality control sampling techniques, resulting in lower inspection costs. But we consider that these matters are already well known, that they are not peculiar to machine tools, and that no special research into them would be justified.

Market Research

62. Professor Melman suggests that there should be research into the possible size and character of the world market for machine tools over the next 10 to 20 years.

63. Such a survey would obviously be full of difficulties, requiring as it would a view to be taken on the development of major using industries throughout the world and an assessment of their likely demand for each category and type of machine tool. Moreover the survey would have to make assumptions on the outcome of various complex situations such as the current economic reorganisation of Western Europe and the rate of industrialisation in under-developed countries. Nevertheless if a survey of this kind could be done on a basis to inspire reasonable confidence, its forecasts would greatly help the taking of decisions affecting the shape of the United Kingdom machine tool industry and the level of investment in it, and would particularly help the planning of research and development (*see* paragraphs 95 to 102). We recommend that the Machine Tool Trades Association should discuss the suggestion in detail with a suitable Agency service, possibly on the basis of a survey limited to 5 or 10 years ahead.

Leasing Machine Tools

64. Professor Melman invites consideration of the possibilities of increasing machine tool markets by leasing, as distinct from selling, machine tools. The machine tool makers represented on the Sub-Committee have told us that in the United Kingdom machine tools are made over by manufacturers to customers in many ways : they are sold for cash on delivery, they are sold on periods of credit ranging from 30 days to 5 years, they are disposed of on a hire purchase basis and they are leased out. Each of these methods accounts for its share of both the domestic and the foreign market for British machine tools, and the facilities for leasing machine tools are tending to increase.

Offsetting Market Fluctuations to Ensure Stable Production

65. Professor Melman proposes that consideration should be given as to whether ways can be found of financing the holding of stocks of machine tools during periods of slack demand so as to allow production to continue at a more stable level. He also asks whether it might not be better to hold stocks of components rather than of complete machines.

66. We find ourselves unable to agree with this proposal, at any rate as a practical means of general application for offsetting market fluctuations, though we recognise that it could be—and indeed is—a useful method for individual firms to adopt on occasions. For example, one large United Kingdom firm during a recent period of six months has sold no fewer than 300 machine tools that had been manufactured but not sold during the recent recession in the industry. But there are obviously limits to which any company can go in regard to the policy of carrying stocks. Were the principle of manufacturing for stock

to be pursued on the scale which Professor Melman has in mind, the industry might be involved in the holding for a period of as long as two or three years of £20-30 million worth of machine tools. Apart from the difficulty of financing such a stock, experience with defence machine tools shows that the subsequent sale of these machine tools, by that time several years old, and possibly superseded by newer designs, is likely to involve considerable losses.

67. We consider that a better way of offsetting market fluctuations is for user firms to be given every encouragement to replace obsolete machine tools during periods of comparatively low industrial activity. To establish the facts on which some incentive could be based we feel that there is need for a census of the age of the machine tools currently in use in United Kingdom industry. We observe that a similar survey was conducted in the United States about 2 years ago under the auspices of the McGraw-Hill Publishing Company. Such surveys are a traditional feature in the United States. We accordingly recommend that an investigation into the age of machine tools currently being operated in the United Kingdom, even if no more than a sample check, should be carried out ; and we consider that the Machine Tool Trades Association should be invited to consider the organisation of such a survey.

PART IV

Other aspects of the United Kingdom Machine Tool Industry

68. In Parts II and III of this Report, we have made a detailed examination of the proposals which Professor Melman has put forward for improving the machine tool industries of Western Europe. We have given our reasons for being unable to accept most of them. We are particularly concerned that this fact should not be taken to mean that we believe there is no room for improvement in the United Kingdom machine tool industry. So anxious are we to make this point clear that we have thought it desirable to offer our views on certain other aspects of the industry, which, although not specifically mentioned by Professor Melman, are in our opinion sufficiently closely connected with the contents of his Report to justify inclusion within our terms of reference.

Criticisms of the Industry's Ability to Respond Quickly to Rises in Demand : Overlong and Unreliable Delivery Dates

69. We start by discussing some of the more common criticisms of the United Kingdom machine tool industry. It should be said at once that, in an industry of such diverse character, any generalisations must be treated with caution, and that many of the criticisms quoted below could certainly not be levelled at some firms. The first criticism is that the industry is too slow in its response to major rises in demand and that its delivery dates are too long and too unreliable. In our view there is a fair basis for this criticism from the customer's point of view, though several important factors in the situation are not within the industry's power to control. Experience shows that whenever a major increase has arisen in the demand for machine tools heavy recourse has

had to be made to imports to meet it. To take an extreme case, at the peak of the Korean rearmament programme 60 per cent. of United Kingdom machine tool supplies were imported. To be fair, however, it should be said that this was at a time when the Government had urged the industry to maintain the level of its exports and not to sub-contract work to other important export industries. In the motor car industry's re-equipment programme of 1955-57, a large part of their machine tool requirements was imported and, although we consider this to have been due primarily to a sudden concentration of demand, the fact remains that the United Kingdom machine tool industry was unable to meet it and as a result valuable orders went abroad.

70. It would be a mistake to conclude that United Kingdom machine tool manufacturers have done nothing to increase the output of the industry. At the time of the Korean rearmament programme, output of machine tools increased by 30 per cent. in one year and by 60 per cent. over three years. But the starting base was comparatively low—amounting to £40 million (£47·2 million on the basis of 1959 prices) in 1950, the lowest figure for any year subsequent to 1954 being £78·8 million in 1959. The corresponding figures of output in the United States by contrast show an increase of 107 per cent. in the first year of the Korean war and 290 per cent. over three years.

71. There is also force in the criticism that delivery periods quoted by the United Kingdom machine tool industry are too long and promises too unreliable except in slack periods, and there is evidence that this factor is still adversely affecting some sections of the export trade.

72. Three main problems arise in connexion with the industry's ability to respond to a rise in demand :

(*a*) Recruitment of additional labour.

(*b*) Spare manufacturing capacity.

(*c*) The possibilities of sub-contracting.

In reviewing these problems we have considered why the machine tool industry in the United States is apparently able to solve them more successfully than the United Kingdom industry.

(*a*) *Recruitment of Additional Labour*

The main obstacle to rapid increases in United Kingdom machine tool output is undoubtedly the difficulty of recruiting additional skilled labour. In our view it would be unfair to compare the ability of the United Kingdom machine tool industry with the ability of industries mass producing consumer goods to respond to sudden upsurges in demand, since the latter are much less dependent on skilled labour. Demands for increased machine tool deliveries coincide with high levels of activity in the engineering industries, when it has been difficult for machine tool firms to recruit the additional skilled labour they need. These conditions have also made it difficult for them to obtain the additional drawing office staff they need. By contrast, there is available in the United States a large pool of fairly skilled and highly mobile labour which is prepared when necessary to work on a three-shift system. In this connexion it has to be remembered that in most parts of the United States the social and economic system is geared to encourage work in factories and elsewhere continuing throughout the 24 hours. A further advantage possessed by the American industry is that its larger-scale production of the different types of machine tool enables it to jig and tool to a greater extent than the United Kingdom industry and so to dilute the proportion of skilled labour required. We have no grounds for suggesting that United Kingdom firms, given their present scale of output should employ a greater degree of tooling, but we point out that the increased batch sizes which would result from the rationalisation of production (paragraph 24) justify greater tooling and would make the industry to that extent less dependent on skilled labour.

(*b*) *Manufacturing Capacity*

While there has been a considerable increase in the output of the United Kingdom machine tool industry since the time of the Korean War (paragraph 70), there is a limit to the extent to which surplus plant can be provided above average requirements in the expectation of suddenly increased demands which may in the event be short-lived. We do not consider that manufacturing facilities as such are the limiting factor in ability to expand output since generally speaking the existing facilities cannot be manned on a multiple shift basis because of the shortage of skilled labour.

(*c*) *Sub-contracting*

According to our information American machine tool firms sub-contract work to a greater extent than their counterparts in the United Kingdom. This practice obviously helps the American firms to meet increases in demand for their products beyond their own capacity to supply, since it enables them to draw on wider manufacturing resources. The United Kingdom machine tool industry has made increasing use of sub-contractors, when it has been under pressure, but any substantial expansion of sub-contracting becomes more difficult to achieve in times of general pressure on the engineering industry.

(*d*) Our conclusion is that the primary obstacle to quick expansion of output in the United Kingdom machine tool industry is the shortage of skilled labour during those periods of high activity in the engineering industries which coincide with high demands for machine tools. More skilled labour could be attracted in some cases by better conditions. We recognise that there are very real difficulties involved in moving some part of machine tool production to Development Districts where competition for labour is less intense than it is in the traditional centres of production, but we consider that managements, particularly those of the larger firms, should study these difficulties further to see whether they could not overcome them.

Alleged Failure by the Industry to Expand Exports and to Hold its Share of World Markets

73. Most of the machine tools built in the United Kingdom are standard machines, which are recognised throughout the world as competitive in quality, price and delivery. Over the years, the industry has supplied home users with almost all their requirements of standard machine tools. At the same time it has exported about 30 per cent. of total production. This is an achievement of which the industry can be proud. But it must be emphasised that, though the exports include some special machine tools, by far the greater proportion are standard machine tools.

74. The United Kingdom machine tool industry has a less impressive record as an exporter than the German and American industries. During 1956-59, the German industry exported 51 per cent. of its machine tool production and imported machine tools equal to 8 per cent. of domestic production ; the American industry exported 20 per cent. and imported 8 per cent.; whilst the United Kingdom industry exported 29 per cent. and imported 23 per cent.

75. During the same period, the United Kingdom share of the world market in machine tools fell from 13 per cent. to 11 per cent., whilst the German share rose from 33 per cent. to 36 per cent. This trend, however, is not confined to the machine tool industry, since over this period in the field of manufactured goods generally Germany increased her share of the world market—often significantly—whilst the United Kingdom share has declined.

76. The pattern of United Kingdom trade in machine tools reveals imports from Germany, Switzerland and the United States far greater than United Kingdom exports to those countries. United Kingdom imports are in fact mainly high performance and high precision advanced types of special machine tools, whilst United Kingdom exports are mainly standard machine tools, many of them to the Commonwealth and the less highly-industrialised countries.

77. We consider that one important reason for the comparatively poor export/import balance of the United Kingdom machine tool industry, and for the shrinkage of the United Kingdom share of the world market, is that the demand for standard machine tools (at home as well as abroad) has increased less rapidly than the demand for the more specialised types which are the object of intensive development effort in Germany and Switzerland. The machine tool manufacturers in Germany are known to attribute their export success primarily to the fact that they can offer a customer any type of machine tool he may require. This policy, the success of which is undeniable, is the very opposite to that advocated by Professor Melman. It is also noteworthy that the American industry has in recent years been able to export as much as 20 per cent. of its production despite high manufacturing costs and the widespread granting to other countries of licences to manufacture American designs. This situation, though it has been assisted by the ability of the American manufacturers to give quick delivery, has in our view been largely brought about by the technical excellence and high performance of certain American machine tools most of which were developed to meet demands from the very large domestic automobile industry. We conclude that the shrinkage of the United Kingdom share of world trade in machine tools is due mainly to over-dependence on the market, valuable though it still is, for standard machine tools and insufficient participation in the more rapidly expanding market for high performance and high precision special types.

78. There is evidence of a growing desire on the part of the United Kingdom industry to achieve major advances in the design of machine tools, resulting in products which will not only meet the needs of home users to an increased extent but will lead also to increased sales abroad. We deal more fully with quality of design and performance in paragraphs 81 and 82 below.

Criticism of Extent of Use of Foreign Designs

79. The criticism is frequently made that too large a proportion of the high performance machine tools in use in the United Kingdom are either imported or made under licence to foreign design. We consider that there is some justification for this criticism.

80. The United Kingdom machine tool industry, however, claim that, in the first place, foreign designs are used under licence, or foreign machine tools are imported, so that users may be offered a full range of machine tools, no matter how specialised they may be. In the second place, many of the machine tools built in the United Kingdom under licence are the result of highly specialised development for which circumstances are favourable in the country of origin and which could not be readily and quickly matched in the United Kingdom. We appreciate these points and recognise that for some machine tools for which the demand in the United Kingdom is limited the initiative for development and manufacture is more likely to lie abroad. We would not wish to make any recommendation which would make it less easy for users to buy the machine tools they want from any source they may choose. We also recognise that, other things being equal, it would be better for a machine tool to be manufactured in the United Kingdom under foreign licence than for it to be imported. We believe, however, that the wide extent to which machine tools of foreign design are at present used in the United Kingdom is a symptom of insufficient development effort here since many of them in fact, given the development capacity, could have been originated in the United Kingdom. We consider that the situation can only be improved by an increased effort on research and development. We make certain recommendations on this point later in this Report. (*See* especially paragraphs 95-102.)

Criticisms of Quality

81. These criticisms can be conveniently considered under two headings :

(*a*) The quality of the product as manufactured.

(*b*) The quality of its design and performance.

As to (*a*) we conclude that there could be no justifiable complaint about the quality of machine tools as they are manufactured in the United Kingdom. In our opinion with the exception of some ultra high precision machines in which the Swiss are predominant the quality of manufacture in the United Kingdom is as good as that in any other country. The evidence of users is unanimous on this point and much credit is due to the United Kingdom machine tool industry on this account. As to (*b*), however, we consider that this criticism is on the whole justified. In a large proportion of the cases in which United Kingdom users import machine tools from abroad the reason is that they cannot get the desired performance from a United Kingdom design. In some cases, this is less a technical than an economic problem, since there is somtimes a strong local reason for the production in a particular country of a highly specialised machine tool, the demand for which is greater and more consistent in that country than it is in the United Kingdom (*e.g.*, small automatics in Switzerland for the watch industry). In such cases it does not pay United Kingdom firms to develop these specialised machines.

82. But when all allowance has been made for special circumstances, and recognising fully some outstanding exceptions, we consider that there is validity in the criticism that there is a lack of progress in the design of many United Kingdom machine tools, and a consequential failure to improve their performance. The main reason for this situation, in our opinion, is the lack of adequate development effort in the United Kingdom machine tool industry ; though again we recognise that exceptions must be made in the case of certain firms.

Reluctance to Meet the Special Needs of Particular Customers

83. This criticism is frequently made and again we regard the criticism as having substantial validity. It is a general comment that foreign firms are prepared to study the special problems of the user and to make or modify machines to suit his particular requirements to an extent that United Kingdom firms (with some exceptions) have not in the past usually been prepared to do. Long order books and the limited market for some of these special features may have played some part in this, but we consider that the main cause has been insufficient development effort by the United Kingdom machine tool industry. Increased effort in research and development is necessary to lessen our dependence on overseas designs of highly specialised and high performance machines and it will at the same time render the United Kingdom manufacturer both more able and more ready to respond to the special demands of domestic and foreign machine tool users.

Productivity per Man-Hour

84. It is sometimes argued and is specifically claimed by Professor Melman that the productivity of the Western machine tool industry is low, that the industry is too much of the " handicraft " type, and that it relies too little on modern mass production techniques.

85. Reliable figures are not available for a true comparison of the productivity per man-hour in the United Kingdom machine tool industry either with that of foreign machine tool industries or with other United Kingdom industries. Machine tool prices are no guide, and the total man-hours sometimes quoted for Soviet machine tools are of little use since it is not clear to what extent bought-in components are included. For example, the mass produced Soviet centre lathe, for which the man-hours by Soviet claims are less than half those required in Western Europe, sells at a domestic price which is almost identical with the domestic price of the equivalent batch produced United Kingdom counterpart. The indications are, however, that, except on mass produced centre lathes and perhaps on one size of radial drill and one size of horizontal borer, the productivity per man-hour in the Soviet machine tool industry is appreciably lower than in the United Kingdom. German estimates on a basis of machine tools per annum per man place Soviet productivity at 48 per cent. of that in Germany.

86. There is a general opinion that on the whole the man-hour productivity in the machine tool industry is somewhat lower in the United Kingdom than in the United States. This is also applicable to industries other than the machine tool industry and is largely attributable to the higher degree of jigging and tooling, greater horsepower provided per operator, and the higher level of

servicing of these operators. There is undoubtedly room for improvement in these respects in a number of United Kingdom firms, but we must record our conclusion that we have not been able to find reliable and truly comparable figures to support any general criticism that productivity in United Kingdom machine tool industry is more than marginally less than it is in the American industry.

Structure of the United Kingdom Machine Tool Industry

87. There are about 350 firms manufacturing machine tools in the United Kingdom, nearly all specialising in a limited range and some concentrating on a single type. In addition there are about 110 firms who as sub-contractors manufacture components or complete machines to order or who include machine tools as a relatively minor item in their output. The total number of people employed on machine tool production is 42,000.

88. Leaving aside the sub-contractors, 20 firms (19,500 employees) supply 50 per cent., 50 firms (28,000 employees) 72 per cent., and 150 firms (36,000 employees) as much as 90 per cent. of the industry's output. The remaining 200 firms (less than 6,000 employees) are thus responsible for no more than 10 per cent. of output, the average turnover of these firms in 1959 being only £40,000 per annum.

89. But although a large number of small firms produce only a minor share of the gross output, their significance should not on this account be underrated. Some of them are specialists—and highly skilled specialists—in particular machine tools of which the total numbers required are, by the nature of the machine, small. Moreover, many small firms can operate on relatively low overheads and their very smallness gives a directness of supervision which results in valuable flexibility in meeting special one-off requirements. These firms are subject to the ordinary pressures of a highly competitive international industry and show remarkable powers of survival. Many of them are likely to continue to play an effective role.

90. Nevertheless it is difficult to believe that small firms generally speaking are in a position to make a sustained development effort and this we believe to be the greatest single need of the industry. To be effective the effort must be backed by adequate numbers of qualified engineers. It is only in exceptional cases that small firms can attract such men and command the financial strength to carry powerful development teams and market the products of novel or advanced design. These requisites are vital to the future of the industry ; and the 20 leading firms, who account for half the industry's output, must bear the main responsibility for achieving the development effort required. The growing awareness on the part of the larger firms of the need for research is of the greatest significance and promise for the future (*see* paragraphs 95 to 102). But we would like to feel more confident that the 20 leading firms were all strong enough to bear this responsibility.

Shortage of Qualified Technical Staff

91. We have referred (paragraph 90) to the need for adequate numbers of qualified engineers in the industry. There is a notable shortage of qualified technical staff, particularly engineers, which in our view constitutes a grave

weakness. Some idea of this deficiency can be gathered from the following set of comparisons :

	Number of Qualified Engineers and Scientists as a percentage of the Total Number of Employees in the Industry	
Industry	*Employed for all purposes* *Per cent.*	*Employed on Research and development* *Per cent.*
Oil refining	7	2·3
Chemical and allied	3·7	1·8
Aircraft	2·7	1·4
Heavy electrical	2·3	1·2
Electrical engineering	2·2	1·25
Electronics	2·1	1·4
Precision instruments, &c.	1·7	1·0
Plant and machinery (not electrical)	1·5	0·39
Machine Tools	*1·3*	*0·29*
Marine engineering	1·1	0·32

92. In 1958, 90 machine tool firms employing 30,000 people had a total of only 25 graduate engineers. The extent to which qualified drawing office personnel is employed in the machine tool industries of the United Kingdom, Germany and Switzerland is shown by the following figures which express the number of such employees as a percentage of the total number of employees in the industries concerned :

	Per cent.
United Kingdom	3·0
Germany	6·6
Switzerland	7·2

Further the Department of Scientific and Industrial Research advise us that the figures for qualified design engineers employed in the machine tool industries of the three countries are similar to those quoted for draughtsmen.

93. From the figures given in paragraphs 91 and 92 it will be seen that the numbers of qualified engineers and draughtsmen employed in the United Kingdom machine tool industry are less than in most other United Kingdom engineering industries and are under half the numbers employed in the German and Swiss machine tool industries.

94. This picture of a serious lack of qualified engineers in the United Kingdom machine tool industry is consistent with the general picture of inadequate development effort, over-dependence on foreign designs and imports for the more advanced machine tools, reluctance to handle the special requirements of particular customers, and the fact that in the markets for high performance machine tools United Kingdom designs are becoming increasingly uncompetitive with those of Germany and Switzerland, where stronger teams of qualified design engineers are employed.

Research and Development

95. We have considered the Report prepared by the Department of Scientific and Industrial Research on the research and development requirements of the United Kingdom machine tool industry. We are glad to know that the conclusions and recommendations of this Report, which are summarised in Appendix B, have been accepted by the Machine Tool Trades Association on behalf of the industry, that a number of measures have already been taken to implement the recommendations, and that others are under consideration.

96. In many places in this Report we have stressed the urgent need for increased research and development to enable the industry to achieve significant advances in machine tool design. We regard this as vital to the industry's future. We consider that development should be directed towards :

(i) Machine tools, incorporating new engineering techniques, especially new control techniques.

(ii) Machine tools combining functions now normally performed on several machines.

(iii) Machine tools capable of producing work consistently to the finer tolerances now required by many sections of the engineering industry.

These three fields of development are closely related ; for example, new techniques will need to be incorporated in the design of machine tools to achieve the higher accuracies now required, and the introduction of automatic control devices has made possible the combination of functions which at present are carried out on successive machine tools because of the need to employ special jigs and fixtures.

97. The Machine Tool Trades Association and the Department of Scientific and Industrial Research agree that the industry's present resources are inadequate for the research and development effort required. The fundamental problem is the shortage of qualified engineers and designers with specialised training in the machine tool field. Measures for improving and increasing the training facilities available at universities and technical colleges are being discussed with the appropriate authorities. Grants for research have already been awarded by the Department to the University of Birmingham, the Manchester College of Science and Technology, the Salford Royal Technical College and the College of Aeronautics at Cranfield, in pursuance of the policy of building up schools of higher training and research. The value of grants so far awarded is a little over £100,000 spread over two years. Finance is not the main factor which limits the Department's activities in this field ; universities and colleges have the same difficulties as industry in recruiting qualified staff for research and for teaching. We believe that the problem of providing facilities for training and research at the universities is part of the problem of providing adequate University Courses in Production Engineering and we suggest that the present facilities are on too small a scale. We emphasise the need for improvement.

98. We recognise that it is difficult for the many small firms in the United Kingdom machine tool industry to maintain adequate research and design staffs. We welcome, therefore, the efforts being made by the Machine Tool Trades Association to establish a co-operative research organisation, which will be a valuable facility to the smaller firms. But we recommend consideration of the possibilities of a combined research institute and teaching centre, on the lines of the Technische Hochschule in Aachen, which is the leading institution of its kind in Germany in the engineering sphere. Aachen has four major faculties, including one which is devoted to machinery and electrical engineering. All studies are of a high technical order, cover four years and can lead to the diploma of the Technische Hochschule. For the first two years, students are required to pursue general studies, whilst in the last two years they are encouraged to specialise. The whole course involves an adequate amount of practical training outside the university. Later specialisation on machine tools

centres round a special laboratory attached to the Machine Construction Department of the Faculty of Machinery and Electrical Engineering. The outstanding feature of the specialist courses on machine tools is that teaching and training are interwoven with practical research which is undertaken on behalf of the German machine tool industry.

99. At the same time in our view it would be wrong to think that the establishment of centralised research facilities will solve the research needs of the industry as a whole or, in particular, that it will remove the urgent need for a major increase in research and development effort in the medium and larger size firms themselves. It must be recognised that the great bulk of research and development must be, and can only be, done internally by private firms, and largely on a proprietorial basis. In this connexion, we warmly welcome the intention of the Department of Scientific and Industrial Research to place contracts for the development of machine tools ; the execution of such contracts will require strong development teams, and they might well, therefore, bring about co-operative arrangements between firms. We recommend moreover that, in placing some of these contracts, the Department should include firms other than machine tool firms in order to bring in, as partners with the machine tool firms, specialists in such fields as electronics, control system engineering, automatic gauging and new metal removal techniques.

100. The Department of Scientific and Industrial Research has already carried out, with the machine tool industry and user industries, a preliminary survey which has made it possible to define the basis on which some development contracts could be placed. For the longer term, however, we recommend that the Department should conduct a further survey with the machine tool industry and user industries in order to determine the probable trends in users requirements and in manufacturing techniques. From this the most profitable broad directions for further machine tool development could be deduced and further specific lines for research and development contracts could be defined. In all this we stress the continuing need for the best advice both from user industries and from supporting industries specialising in electronics, data processing, control engineering, &c.

101. We understand that the United Kingdom machine tool industry currently spends about £3 million a year on research and development. In our view, this is insufficient for an industry of its size and national importance ; and we consider that the figure should be increased to about 10 per cent. of the industry's turnover, say to £8 million a year by the end of 1964. The greater part of the increased expenditure would be on work more extensive in scope but of similar character to that on which the industry is now engaged. This expenditure which the industry must undertake, offers fair prospects of financial return in a reasonable time. There is, however, an urgent need for more work of a fundamental character and for the application of the results of research to provide major advances in design. This work, which we assess will require about 20 per cent. of the proposed increase, may well be both costly and highly speculative and can properly be regarded as qualifying for assistance from public funds. Its commercial value to the machine tool industry would at best be long term.

102. In paragraph 101 we express the view that the research and development expenditure by the industry should be increased from the current level of £3 million a year to about £8 million a year over a period of four years. This will necessitate an increase in the numbers of qualified personnel now engaged in the work of this character in the industry. Some 120 are at present so employed. We believe that, if this enlarged programme of research and development is accepted, the additional number of qualified personnel required will be of the order of 350, of whom 50 to 100 will be needed in the supporting industries (*see* paragraph 99). So urgent is the need for increased research and development effort, however, that the machine tool industry cannot afford to await the arrival of younger men who have taken advantage of the specialised training facilities which are now becoming available (*see* paragraph 97) ; they will have to secure the qualified personnel they need by attracting from other industries men who have already a good basic engineering education. It will require a special effort, particularly in the early stages of the campaign, to attract to the machine tool industry young men of ability with high technical qualifications on the lookout for career opportunities leading to a dynamic future. Given good career prospects, we do not believe that a recruitment of the numbers of qualified engineers and scientists we have in mind should prove beyond the ability of an industry of such obvious national importance.

PART V

Conclusions

103. Mass production refers to production lines specially set up for the production of one specific product for a long period (paragraph 9). The product must be standardised and the demand high and stable (paragraph 12). Mass production methods could quickly be introduced by machine tool manufacturers who foresaw a sufficiently high and stable demand for their products (paragraph 17).

104. Despite the exceptional conditions in the U.S.S.R. (paragraph 15) the Soviet have so far been able to apply mass production methods to only a small sector of machine tool production and by far the greater part of the output is made by the same production methods as in the West (paragraph 11).

105. This limited use of mass production methods in the U.S.S.R. depends on a degree of regimentation and control unacceptable to democratic countries (paragraph 15). No single country outside the Communist *bloc* has a demand sufficiently high for any one type of machine tool to justify mass production methods (paragraph 12). Even if the international difficulties of standardising demand and centralising production in Western Europe were to be overcome (paragraphs 12 and 13) we believe that the demand for any one type would still be too low to justify mass production methods (paragraph 14).

106. Moreover the extreme standardisation of design, and therefore of performance, implicit in mass production, would fail to meet the majority of the needs of the user industries for high performance, specialised machine tools. Standardisation of machine tools to the extent necessary for their mass production

would in general raise the manufacturing costs of the products made by the machine tools, and it is these costs not the price of the machine tool itself, that must be the dominant consideration (paragraphs 16, 41, 47, 48).

107. For these reasons we reject Professor Melman's main recommendation that mass production of machine tools must be introduced rapidly into the machine tool industry of Western Europe (paragraph 26). We recognise, however, that important advantages are obtained when manufacture is carried out in large production units and consider that there remains scope for further rationalisation in some sectors of the United Kingdom industry.

108. We appreciate the sincerity with which Professor Melman has stressed the likelihood of an early threat in third markets from Soviet machine tools. We point out that the economic system of the Communist *bloc* in any case enables them to sell overseas at prices which do not reflect costs of production and that they may also be ready to offer loans and favourable credit terms to particular countries. We consider that so far as manufacturers are concerned, the best counter to this threat is technical superiority of their product which cannot be affected by politico-economic factors (paragraphs 18 and 19). In this connexion we stress the importance which Western observers should attach to the intense effort applied in the Communist *bloc* to research and development (paragraph 23).

109. The enquiries proposed by Professor Melman were related to the main concept which we have rejected. They have, however, formed a useful basis for a wide-ranging discussion with manufacturers and users as a result of which we make the following recommendations :

(i) The scope for further standardisation of components is limited except as a sequel to any reductions in the number of designs of machine tools that may arise from rationalisation between firms making similar products, but there is both scope and need for further standardisation of those parts of machine tools of primary importance to users, particularly features which are associated with the attachment and location of tooling and ancillary equipment. The machine tool industry should set up an effective organisation to establish greater standardisation in those areas (paragraph 33).

(ii) Leading manufactures of unit head and multi-station machines should collaborate to achieve greater standardisation of assembly and location details and as an immediate step the machine tool industry should adopt the standards for modular units recently adopted by the American automobile industry (paragraph 36).

(iii) The Machine Tool Trades Association, British Standards Institution and the Federation of British Industries should be invited to consider the desirability of recruiting technical staff in order to speed up the process of formulating new standards (paragraph 44).

(iv) We are impressed by the achievements of electronic firms concerned with machine tool control. We note that using industries seem to be slow in recognising the advantages of the more complex forms of electronic control of machine tools, suggest that this is probably because of the lack of unchallengeable factual cost information on these new techniques and note that a report on a useful series of trials carried out in Royal Ordnance Factories is shortly to be published. We believe that further trials, of wider scope and under the direction of an independent authority, should be carried out and we recommend that the Government should consider whether their resources could usefully be made available to assist these experiments (paragraph 59 (*d*)).

(v) We hold that machine tool firms should not enter the field of electronic manufacture, but should maintain close links with electronic firms and to this end recruit suitably qualified engineers (paragraph 59 (*e*)).

(vi) We draw attention to the need for a more basic approach to the problem of applying electronic techniques to machine tools. We mention problems on which research and development work is required by joint teams of machine tool and electronic control system engineers. We recommend that this work should be carried out in industry partly through development contracts placed by the appropriate Government Department (paragraph 59 (*g*)).

(vii) A market survey of the likely demand for machine tools for 5-10 years ahead would be of great value to the industry. We appreciate the difficulties in such a survey, but suggest that the Machine Tool Trades Association should discuss its feasibility with a suitable Agency (paragraph 63).

(viii) The Machine Tool Trades Association should be invited to organise a survey, if no more than a sample check, of the age of machine tools currently operated in the United Kingdom (paragraph 67).

110. We are particularly concerned that our rejection of Professor Melman's main recommendation and of most of his specific suggestions should not be taken to mean that we believe there is no room for improvement in the United Kingdom industry. With this in mind we offer our views on various aspects of the industry not specifically mentioned by Professor Melman (Part IV).

111. We have examined (paragraphs 69-72) the criticism that the British machine tool industry does not respond quickly to rises in demand. We consider that comparisons with the industry in the United States, which is more successful in this respect, are unhelpful as conditions differ so radically. The main obstacle to rapid increase in United Kingdom machine tool output is the difficulty of recruiting additional skilled labour. We suggest that there may be occasions when the machine tool industry should attract more skilled labour by better conditions and recommend that at present managements should consider further how they might overcome the difficulties involved in moving part of their production to Development Districts.

112. We are struck by the fact that there is little complaint about the quality of manufacture of United Kingdom machine tools (paragraph 81). The United Kingdom industry is recognised throughout the world as an excellent producer of standard machine tools of all categories ; it supplies almost the whole home demand for such machine tools and exports approximately 30 per cent. of its production (paragraph 73). But the demand for such machines, though it will continue to be heavy, has not recently increased as rapidly as the demand for more complex types, and this tendency, particularly as under-developed countries start manufacturing the simpler types of standard machines, is likely to continue (paragraphs 20 and 21).

113. We consider that as a generalisation it is safe to say that the performance of the United Kingdom industry in comparison with its Western competitors suffers from over-concentration on the production of standard machine tools and that this accounts for its shrinking share of the increased world trade (paragraph 77) and for the high proportion of machines imported into this country (paragraph 74)—(which reduce the industry's performance as a net exporter to 6 per cent.).

114. Basically this over-concentration on standard types springs in our view from the lack of a sufficiently intensive development effort. This same factor accounts for much of the criticism that our industry is over-dependent on licensing agreements to manufacture machine tools of foreign design (paragraphs 79 and 80) and that it is reluctant to meet the special needs of particular customers (paragraph 83). Behind this weakness lies a shortage in the industry of qualified technical staff (paragraphs 91-94 and 97 and 59 (*e*) and (*f*)). (This shortage must also imply in some sectors a weakness in production techniques (paragraph 56) though we do not believe this weakness to be widespread.)

115. The basic shortage of specialised staff for research and development is being actively tackled (paragraph 97). Meanwhile we stress that well qualified engineers can usually be found by any firm that shows these men a company structure big enough to offer a good career and a development effort big enough to ensure a dynamic future.

116. We note that the intention of the Department of Scientific and Industrial Research to place development contracts will require strong development teams and will thus encourage co-operative arrangements between machine tool firms. We recommend that in placing some of these contracts the Department should include specialist firms outside the machine tool field (paragraph 99).

117. As the whole tenor of our Report is to the effect that the key to the industry's future lies in technical excellence—

(i) We welcome the efforts being made by the industry to establish a co-operative Research Association and we recommend that the possibilities of linking this with a teaching centre on the lines of the Technische Hochschule in Aachen, should be investigated (paragraph 98).

(ii) We consider that the present rate of research and development by the industry (estimated at £3 million per annum) is much too small and that the figure should be increased to 10 per cent. of the industry's turnover, say, to £8 million a year by the end of 1964. Some 20 per cent. of this proposed increase should relate to work of a more fundamental character of at best only long-term commercial value to the machine tool industry. We regard this as properly qualifying for assistance from public funds (paragraph 101).

(iii) To handle these increases in research and development we consider that some 250-300 additional qualified engineers and scientists must be attracted to the machine tool industry by 1964. We think this can be achieved (paragraph 102).

(iv) We recommend that the development programmes at (ii) above should be based on an analysis jointly by the Department of Scientific and Industrial Research, the machine tool industry, and the user industries, of the long-term future trends of both manufactures and of manufacturing techniques in order that the most profitable lines of development can be established. We stress the continuing importance in this development planning of close consultation with the user industries and with neighbouring technologies such as electronics, control engineering, data processing, &c. (paragraph 100).

(v) It is our considered view that the greatest single need to-day of the British machine tool industry is for a major increase in development effort by qualified engineers.

118. Though we have been unable to endorse Professor Melman's principal recommendation that Western Europe should mass produce machine tools or the majority of his specific recommendations, we have welcomed the opportunity which the detailed examination has afforded for considering the problems and the prospects of the United Kingdom machine tool industry. The more deeply we have probed into the problems the more we have felt how difficult it is to make useful generalisations about an industry necessarily so diverse. We feel that this may in part, but only in part, explain why the industry has so frequently in the past failed to explain itself to the public.

119. Our own report must in part be critical as we aim at showing how the industry can better its performance. We hope that energy will not be wasted either in unfairly exploiting these criticisms or in unnecessary defence against them. Men working in this industry can rightly be proud of its past and present achievements. What matters, however, is the future and we are confident that our main recommendations point the way. This is an industry of such importance and promise that it offers an exciting challenge not only to the able men already working in it, but to many others who may not yet have thought of it as a likely field for their skill and enterprise.

September 1960.

APPENDIX A

Summary of the views of the Machine Tool Manufacturing Members of the Sub-Committee on the Soviet threat to United Kingdom Exports of Machine Tools

There is no reason to suppose that Soviet machine tools are technically superior to machine tools made in the United Kingdom. Other things being equal, therefore, there should be no more than a normally competitive threat from the Soviet industry either in the United Kingdom's traditional export markets or in countries which, because they are embarking on industrialisation, are creating a new demand for machine tools.

2. The Soviet threat to machine tool export markets is a comparatively recent development. In the main and so far, it concerns the smaller and simpler types of general purpose machines, *e.g.*, centre lathes in sizes up to 13-in. swing, plain horizontal and vertical milling machines, shapers, pillar and radial drills and plain grinders. But, though the U.S.S.R. have in operation plans for the mass production of the comparatively simple machines suitable for countries which are embarking on industrialisation programmes, it is also clear that they have established a large and effective machine tool industry which is already producing more advanced machines equal, though not necessarily superior, to similar Western products.

3. All the evidence suggest then that the U.S.S.R. is making considerable technological progress, and that her machine tool industry is continually being strengthened and extended. Under normal conditions, therefore, it would seem that the Soviet threat will pose serious problems for the machine tool industries of the United Kingdom and the Western countries. But the threat is undoubtedly intensified by the existence of special considerations of an essentially political character.

(i) Where they think necessary in order to penetrate markets, the U.S.S.R. are prepared to offer extended terms of payment, to accept payment in the currency of the purchasing country, and to indulge in barter transactions. The prices which the U.S.S.R. quote may moreover be fixed on political grounds, or on grounds of economic strategy, rather than on purely commercial grounds. They have granted a loan of £134 million to India in order to finance the establishment and equipment of industrial plants there : they have advanced loans and credits to the United Arab Republic : whilst the Poles have offered a loan of £11 million to India for use in the purchasing of engineering equipment.

(ii) The Soviet Government spend money on advertising, and on sponsoring trade exhibitions on a scale which private companies in Western countries cannot possibly match.

(iii) The Soviet Government press the claims of their machine tool industry on every possible occasion, and they insist on quotas for machine tools being written into all appropriate trade agreements. Furthermore, Soviet diplomatic missions are dedicated to furthering the industrial interests of the U.S.S.R. in the countries to which they are accredited.

4. The Soviet competitive threat in the machine tool field falls into two phases :

(*a*) The immediate fact of penetration into the less highly developed countries.

(*b*) The longer term attempt to achieve technical superiority over the West.

5. The financial information mentioned at (i) above constitutes clear evidence in support of (*a*). Individual manufacturers and even industrial groups in the West can scarcely be expected to match Soviet financial inducements to countries which are anxious to secure all the extended credits and the loans they can get. Within its own boundaries the Communist *bloc* has complete control of production and consumption so that there is a tremendous pool of demand which can be fed or starved at will, in accordance with the dictates of politico-economic strategy. Apart from loss of United Kingdom trade in traditionally important markets, there will be the broader psychological effects on the people of countries like India when they see the machines on which the raising of their living standards depends imported from the

U.S.S.R. instead of from the United Kingdom and other Western countries. Africa and Latin America are obviously promising fields for Soviet penetration.

6. As regards (*b*), it is the avowed intention of the U.S.S.R. to overhaul and then to surpass the West in industrial development, and so basic an industry as machine tools must loom large in their strategic economic thinking and planning. They consider that industrial superiority will pave the way for economic and political penetration, especially into the less highly industrialised countries of the world. But the process of attempting to achieve industrial superiority will necessarily involve increased concentration in the Communist *bloc* on the production of the more advanced types of machine tool and in consequence less mass-production of the simpler types. All of which could mean that longer-term competition between the Communist *bloc* on the one hand and the countries of the West on the other, may be on a basis which in the West is accepted as more normal; the governing factors being quality, cost and service.

7. Summarising the views of the three representatives of the machine tool industry, they are :

(i) The Soviet threat to United Kingdom exports of certain types of machine tool is a very real one now and can be expected to intensify in the future. The political angle can only serve to increase this threat and it will apply particularly to the less highly industrialised countries.

(ii) In the case of high-production and special custom-built machines, the greater flexibility of design, coupled with high-grade technical selling, should enable United Kingdom manufacturers to compete adequately —but only if constant work is carried on in the design, research and development fields. Even here, the political factor will weigh heavily against United Kingdom manufacturers, unless it can be either controlled or countered.

APPENDIX B

Report by the Department of Scientific and Industrial Research on the Research and Development Requirements of the United Kingdom Machine Tool Industry

(SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS)

The survey of the research and development requirements of the United Kingdom machine tool industry was carried out with the fullest co-operation of the Machine Tool Trades Association, who afforded facilities for the study of the production, design, development and research activities of over 40 of the leading companies in the industry. The main conclusion of the enquiry was that the industry would benefit from being able to recruit much larger numbers of designers and engineers specially trained in the technologies appropriate to the industry. At the present time, facilities for training such specialists appear to be inadequate in the United Kingdom. The report, therefore, recommended :

(1) That these conclusions should be brought to the attention of the authorities responsible for education and technical training, namely, the Ministry of Education and the University Grants Committee.

(2) That because of the shortage of teachers in the appropriate subjects, the industry itself should help in all possible ways.

(3) That schools of research in machine tool technology should be encouraged in appropriate centres and that the industry and the Government should co-operate in providing resources for this development.

(4) That the machine tool industry should consider how it could make greater use of the research facilities provided by Government Research Stations and grant-aided Research Associations and whether it should establish a research or design organisation of its own.

(5) That the Department of Scientific and Industrial Research should consider what measures could be taken to make its existing resources of more effective use to engineers and designers in the industry.

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